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IB/04/3614

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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R C van Dijk

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Information carrier intended to store data

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Information carrier intended to store data

FIELD OF THE INVENTION

The invention relates to new types of information carriers intended to store data, as well as methods for defining data pattern in such information carriers.

The invention may be used in the field of optical data storage.

BACKGROUND OF THE INVENTION

The use of optical storage is nowadays widespread for content distribution, for example in storage systems based on the DVD (Digital Versatile Disc) standards. Optical storage has a big advantage over hard-disc and solid-state storage in that the information carrier are easy and cheap to replicate.

However, due to the large amount of moving parts in the drives, known applications using this type of storage are not robust to shocks when performing read operations, considering the required stability of said moving parts during such operations. As a consequence, known optical storage solutions cannot easily be used in applications which are subject to shocks, such as in portable devices.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to propose an information carrier comprising :

- a mask layer defining a data pattern,
- a detection layer stacked on said mask layer and comprising at least one segment made of organic photosensitive material embedded between electrodes for detecting said data pattern.

The segments acting as sensors for detecting data are part of the information carrier. In this way, problems with alignment between a data medium and a separate detector are avoided. This information carrier is robust to shocks since it forms a single unit.

In a preferred embodiment, the data pattern is made of substantially transparent and non-transparent elementary areas.

This way of coding information is easy and cost-effective.

In a preferred embodiment, each sensor is sized for facing a plurality of elementary areas.

This allows increasing storage capacity in a cost-effective manner.

It is also an object of the invention to propose an information carrier comprising a layer comprising at least one segment, said at least one segment comprising active and passive elementary areas for defining a data pattern, said at least one segment being made of organic photosensitive material embedded between electrodes for detecting said data pattern.

This information carrier takes advantage of the possibilities of a LED segment to be locally passivated. By this way, the single layer is not only used as a data detector, but also as a data medium. In this embodiment, the mask layer is replaced by a data pattern defined by a sequence of active and passive elementary areas. This information carrier is also robust to shocks since it forms a single unit.

It is also an object of the invention to propose an information carrier comprising a plurality of layers stacked on top of each other, each layer comprising at least one segment, said at least one segment comprising active and passive elementary areas for defining a data pattern, said at least one segment being made of organic photosensitive material embedded between electrodes for detecting said data pattern.

This multi-layers embodiment allows increasing the storage capacity.

It is also an object of the invention to propose a method of defining a data pattern in an information carrier comprising a detection layer, said data pattern deriving from a step of printing dark elementary areas on said detection layer.

It is also an object of the invention to propose a method of defining a data pattern in an information carrier comprising a layer made of organic photosensitive material, said data pattern deriving from a step of modifying the properties of said material for creating passive elementary areas.

It is also an object of the invention to propose a method of defining a data pattern in an information carrier comprising a layer made of organic photosensitive material embedded between electrodes, said data pattern deriving from a step of suppressing one of said electrodes for creating passive elementary areas.

Detailed explanations and other aspects of the invention will be given below.

BRIEF DESCRIPTION OF THE DRAWINGS

The particular aspects of the invention will now be explained with reference to the embodiments described hereinafter and considered in connection with the accompanying drawings, in which identical parts or sub-steps are designated in the same manner :

Fig.1 depicts a first embodiment of a system for reading an information carrier,

Fig.2 depicts a second embodiment of a system for reading an information carrier,

Fig.3 depicts a first arrangement for moving the systems depicted in Fig.1 and Fig.2 over an information carrier,

Fig.4 depicts a second arrangement for moving the systems depicted in Fig.1 and Fig.2 over an information carrier,

Fig.5 depicts detailed elements of the second arrangement depicted in Fig.4,

Fig.6 depicts a detailed view of components used for macro-cell scanning,

Fig.7 illustrates the principle of macro-cell scanning,

Fig.8 depicts a three-dimensional view of the second system depicted in Fig.2,

Fig.9 depicts a detector made of an array of LED segments,

Fig.10 depicts a current-voltage curve of a LED segments,

Fig.11 depicts a first information carrier according to the invention,

Fig.12 illustrates by an example data storage in the first information carrier according to the invention,

Fig.13 depicts a second information carrier according to the invention,

Fig.14 illustrates by an example data storage in the second information carrier according to the invention,

Fig.15 depicts a third type of information carrier according to the invention,

Fig.16 illustrates the principle of photo-oxidation of a LED segment.

DETAILED DESCRIPTION OF THE INVENTION

Fig.1 and Fig.2 depicts a first and second embodiment of a system for reading data stored on an information carrier.

The information carrier is intended to store binary data organized according to an array (as in a data matrix), and is intended to be read in transmission The information carrier comprises a mask layer made of glass or plastic. The mask layer comprises substantially transparent and non-transparent areas for defining a data pattern representing states of binary data stored on the information carrier.

The embodiment of Fig.1 comprises an optical element 102 for generating an array of light spots 103 from an input light beam 104, said array of light spots 103 being intended to scan the information carrier 101.

The optical element 102 corresponds to a two-dimensional array of micro-lenses at the input of which the coherent input light beam 104 is applied. The array of micro-lenses 102 is placed parallel and distant from the information carrier 101 so that light spots are focussed on the information carrier. The numerical aperture and quality of the micro-lenses determines the size of the light spots. For example, a two-dimensional array of micro-lenses 102 having a numerical aperture which equals 0.3 can be used. The input light beam 104 can be realized by a waveguide (not represented) for expanding an input laser beam, or by a two-dimensional array of coupled micro lasers.

The light spots are applied on transparent or non-transparent areas of the information carrier 101. If a light spot is applied on a non-transparent area, no output light beam is generated in response by the information carrier. If a light spot is applied on a transparent area, an output light beam is generated in response by the information carrier, said output light beam being detected by the detector 105. The detector 105 is thus used for detecting the binary value of the data of the area on which the optical spot is applied.

The detector 105 is advantageously made of an array of CMOS or CCD sensors. For example, one sensor of the detector is placed opposite an elementary area containing one data (i.e. one bit) of the information carrier. In that case, one sensor of the detector is intended to detect one data of the information carrier.

The embodiment of Fig.2 comprises an optical element 202 for generating an array of light spots 203 from an input light beam 204, said array of light spots 203 being intended to scan the information carrier 201.

The optical element 202 corresponds to a two-dimensional array of apertures at the input of which the coherent input light beam 204 is applied. The apertures correspond for example to circular holes having a diameter of 1 μm or much smaller. The input light beam 204 can be realized by a waveguide (not represented) for expanding an input laser beam, or by a two-dimensional array of coupled micro lasers.

The light spots are applied on transparent or non-transparent areas of the information carrier 201. If a light spot is applied on a non-transparent area, no output light beam is generated in response by the information carrier. If a light spot is applied on a transparent area, an output light beam is generated in response by the information carrier, said output light beam being detected by the detector 205. Similarly as the first embodiment depicted in Fig.1, the detector 205 is used for detecting the binary value of the data of the area on which the optical spot is applied.

The detector 205 is advantageously made of an array of CMOS or CCD sensors. For example, one sensor of the detector is placed opposite an elementary area containing a data of the information carrier. In that case, one sensor of the detector is intended to detect one data of the information carrier.

The array of light spots 203 is generated by the array of apertures 202 in exploiting the Talbot effect which is a diffraction phenomenon working as follow. When a number of coherent light emitters of the same wavelength, such as the input light beam 204, are applied to an object having a periodic diffractive structure, such as the array of apertures 202, the diffracted lights recombines into identical images of the emitters at a plane located at a predictable distance z0 from the diffracting structure. This distance z0 is known as the Talbot distance. The Talbot distance z0 is given by the relation $z0 = 2.n.d^2 / \lambda$, where d is the periodic spacing of the light emitters, λ is the wavelength of the input light beam, and n is the refractive index of the propagation space. More generally, re-imaging takes place at other distances z(m) spaced further from the emitters and which are a multiple of the Talbot distance z such that $z(m) = 2.n.m.d^2 / \lambda$, where m is an integer. Such a re-imaging also takes place for m = ½ + an integer, but here the image is shifted over half a period. The re-imaging also takes place for m = ¼ + an integer, and for m = 3/4 + an integer, but the image has a doubled frequency which means that the periodicity of the apertures is halved with respect to that of the array of apertures.

Exploiting the Talbot effect allows generating an array of light spots of high quality at a relatively large distance from the array of apertures 202 (a few hundreds of µm, expressed by z(m)), without the need of optical lenses. This allows inserting for example a cover layer between the array of aperture 202 and the information carrier 201 for preventing the latter from contamination (e.g. dust, finger prints ...). Moreover, this facilitates the implementation and allows increasing in a cost-effective manner, compared to the use of an array of micro-lenses, the density of light spots which are applied to the information carrier.

Fig.6 depicts a detailed view of the system depicted in Fig.1 and Fig.2. It depicts a detector 605 which is intended to detect data from output light beams generated by the information carrier 601. The detector comprises sensors referred to as S1-S2-S3, the number of sensors represented being limited for facilitating the understanding. In particular, sensor S1 is intended to detect data stored on the data area DA1 of the information carrier, sensor S2 is intended to detect data stored on the data area DA2, and sensor S3 is intended to detect data stored on the data area DA3. Each data area (also called macro-cell) comprises a set of elementary data areas for storing elementary data. For example, data area DA1 comprises elementary data areas referred to as EA1a-EA1b-EA1c-EA1d.

In this embodiment, one sensor of the detector is intended to detect a set of data, each elementary data among this set of data being successively read by a single light spot generated either by the array of micro-lenses 102 depicted in Fig.1, or by the array of apertures depicted in Fig.2. In the following, this way of reading data on the information carrier is called macro-cell scanning.

Fig.7, which is based on Fig.6, illustrates a non-limitative example of the macro-cell scanning of an information carrier 701.

Data stored on the information carrier 701 have two states indicated either by a black area (i.e. non-transparent) or white area (i.e. transparent). For example, a black area corresponds to a "0" binary state while a white area corresponds to a "1" binary state.

When a sensor of the detector 705 is illuminated by an output light beam generated by the information carrier 701, the sensor is represented by a white area. In that case, the sensor delivers an electric output signal (not represented) having a first state. On the contrary, when a sensor of the detector 705 does not receive any output light beam from the

information carrier, the sensor is represented by a cross-hatched area. In that case, the sensor delivers an electric output signal (not represented) having a second state.

In this example, each set of data comprises four elementary data, and a single light spot is applied simultaneously to each set of data. The scanning of the information carrier 701 by the light spots 703 is performed for example from left to right, with an incremental lateral displacement which equals the distance between two elementary data.

In position A, all the light spots are applied to non-transparent areas so that all sensors of the detector are in the second state.

In position B, after displacement of the light spots to the right, the light spot to the left side is applied to a transparent area so that the corresponding sensor is in the first state, while the two other light spots are applied to non-transparent areas so that the two corresponding sensors of the detector are in the second state.

In position C, after displacement of the light spots to the right, the light spot to the left side is applied to a non-transparent area so that the corresponding sensor is in the second state, while the two other light spots are applied to transparent areas so that the two corresponding sensors of the detector are in the first state.

In position D, after displacement of the light spots to the right, the central light spot is applied to a non-transparent area so that the corresponding sensor is in the second state, while the two other light spots are applied to transparent areas so that the two corresponding sensors of the detector are in the first state.

The scanning of the information carrier 701 is complete when the light spots have been applied to all data of a set of data facing a sensor of the detector. Since the light spots applied to the information carrier form a two-dimensional array, a set of data opposite a sensor of the detector is read successively lines of elementary data after lines of elementary data, and elementary data after elementary data for a given line of elementary data. It implies a two-dimensional scanning of the information carrier.

The illustration presented in Fig.7 is non-limitative also in the fact that instead of reading binary elementary data, the data could be coded at higher resolution, for instance in using multilevel schemes. An example would be a scheme where two elementary bits are detected per pixel, by means of distinguishing four grey levels (0, 1/4, 1/2, 3/4). This would double the data density over a system using a binary coding.

Fig.8 depicts a three-dimensional view of the system as depicted in Fig.2. It comprises an array of apertures 802 for generating an array of light spots applied to the information carrier 801. Each light spot is applied and scanned over a two-dimensional set of data of the information carrier 801 (represented by bold squares). In response to this light spot, the information carrier generates (or not, if the light spot is applied to a non-transparent area) an output light beam in response which is detected by the sensor of the detector 805 opposite the set of data which is scanned. The scanning of the information carrier 801 is performed in displacing the array of apertures 802 along the x and y axis.

The array of apertures 802, the information carrier 801 and the detector 805 are stacked in parallel planes. The only moving part is the array of apertures 802.

It is noted that the three-dimensional view of the system as depicted in Fig.1 would be the same as the one depicted in Fig.8 in replacing the array of apertures 802 by the array of micro-lenses 102.

The scanning of the information carrier by the array of light spots is done in a plane parallel to the information carrier. A scanning device provides translational movement in the two directions x and y for scanning all the surface of the information carrier.

In a first solution depicted in Fig.3, the scanning device corresponds to an H-bridge. The optical element generating the array of light spots (i.e. the array of micro-lenses or the array of apertures) is implemented in a first sledge 301 which is movable along the y axis compared to a second sledge 302. To this end, the first sledge 301 comprises joints 303-304-305-306 in contact with guides 307-308. The second sledge 302 is movable along the x axis by means of joints 311-312-313-314 in contact with giides 309-310. The sledges 301 and 302 are translated by means of actuators (not represented), such as by step-by-step motors, magnetic or piezoelectric actuators acting as jacks.

In a second solution depicted in Fig.4, the scanning device is maintained in a frame 401. The elements used for suspending the frame 401 are depicted in a detailed three-dimensional view in Fig.5. These elements comprise :

- a first leaf spring 402,
- a second leaf spring 403,
- a first piezoelectric element 404 providing the actuation of the scanning device 401 along the x axis,

- a second piezoelectric element 405 providing the actuation of the scanning device 401 along the y axis.

The second solution depicted in Fig.4 has less mechanical transmissions than the H-bridge solution depicted in Fig.3. The piezoelectric elements, in contact with the frame 401, are electrically controlled (not represented) so that a voltage variation results in a dimension change of the piezoelectric elements, leading to a displacement of the frame 401 along the x and/or the y axis.

The position P1 depicts the scanning device 401 in a first position, while the position P2 depicts the scanning device 401 in a second position after translation along the x axis. The flexibility of the leaf springs 402 and 403 is put in evidence.

A similar configuration can be built with four piezoelectric elements, the two extra piezoelectric elements replacing the leaf springs 402 and 403. In that case, opposite pair of piezoelectric elements act together in one dimension in the same way as an antagonist pair of muscles.

Alternatively, detectors 105-205 used in Fig.1 and Fig.2 respectively are advantageously made of an array of segments acting as sensors, each sensor being made of organic photosensitive material embedded between electrodes. Such a detector is depicted in Fig.9.

The segments of the detector are made of organic light emitting diodes (OLEDs), small molecule OLEDs (smOLEDs), polymer OLEDs (PolyLED), frozen/doped light emitting electrochemical cells (LEECs), organic photovoltaic cells, or hybrid organic/inorganic solar cell known as Grätzel cell. In the following, these sensors will be referred to as LED segments.

This detector is equivalent to a pixelated matrix in which each element of the matrix corresponds to a LED segment acting as a sensor. The detector comprises electrical contacts at its periphery : electrical contacts C_R for addressing the rows of the detector, and electrical contacts C_C for addressing the columns of the detectors.

The electrical contacts are either dedicated to receive electric power from a player in which the information carrier is inserted, and to output signals generated by the LED segments to said player.

Every segment of the matrix is driven individually by electronic circuits and logics via the electrical contacts. Electronic circuits and logics can be incorporated directly in the substrate of the detector for defining an active matrix detector. In that case, the state of a plurality of segments acting as sensors can be read simultaneously. Electronic circuits and logics can also be situated externally in the player for defining a passive matrix detector. In that case, no circuitry is incorporated on the substrate apart from feed lines. Reading operation is driven by addressing rows and columns in such a way that one row displays information at a time. Changing rows in a fast way builds up a total image of the detector.

Fig.10 represents a typical current-voltage curve of a LED segment. This figure shows that above a polarization threshold TH, a LED segment acts as a light emitter, whereas below that threshold TH, a LED segment acts as a light receiver. In the context of the invention, the LED segment is polarized with a voltage V such that it acts as a light receiver. Preferably, the voltage V is negative for improving the light detection.

Fig.11 depicts a cross-section of an information carrier according to the invention. This information carrier comprises either means for representing stored data and means for detecting said data. This information carrier takes advantage of the small thickness of LED segments, which allows stacking LED segments and the mask layer for defining a single unit. This information carrier comprises a mask layer ML and a detection layer DL :

- the mask layer ML defines the data pattern of data which are intended to be stored. The mask layer can be made of glass or plastic in which data pattern is made of substantially transparent and non-transparent elementary areas representing the states of binary data to be stored. Alternatively, the substantially non-transparent elementary areas are made by a step of printing dark elementary areas on the surface of the detection layer DL (laser or inkjet printing).
- the detection layer DL is stacked on the mask layer ML and comprises LED segments S1-S9 acting as sensors (this number of segments being not limitative). For increasing the storage capacity, one segment is preferably sized (as represented) for facing a matrix comprising a plurality of elementary areas (i.e. defining a plurality of bits) in using macro-cell scanning as previously described. Alternatively, one segment is

more basically sized for facing a single elementary area (i.e. defining a single bit) without using macro-cell scanning.

Fig.12 illustrates by an example the macro-cell scanning of two adjacent macro-cell data in an information carrier according to the invention as described in Fig.11. The data pattern is created by the mask layer attached to the detector in defining substantially non-transparent elementary areas (black squares) and substantially transparent elementary areas (white squares). Segment S3 faces a macro-cell data scanned optically by the light spot LS3, while segment S4 faces a macro-cell data scanned optically by the light spot LS4. The light spots are simultaneously and laterally displaced (by actuation means not represented) along the scanning direction D so that a light spot each is applied on each elementary area of each macro-cell data. When an elementary areas is scanned by a light spot, the corresponding segment generates a two-levels output signal : a first level L when the scanned elementary area is substantially non-transparent and a second level H when the scanned elementary area is substantially transparent. It allows generating transmission output signals T3 and T4 reflecting the binary data pattern stored in the mask layer.

Fig.13 depicts a cross-section of an improved information carrier according to the invention comprising a single layer L1 made of organic photosensitive material. This single layer not only plays the role of a detector in using LED segments acting as sensors, but also the role of a data medium since each segment comprises active and passive elementary areas for defining a data pattern.

The information carrier comprises segments S1-S9 (this number of segments being not limitative), each segment comprising a plurality of active and passive elementary areas represented by rectangles.

Active elementary areas, correspond to areas where the properties of the LED segment remain unchanged. When applying an input light spot on an active elementary area, an output signal having a first state is generated by the corresponding LED segment so that a first state of the binary data is derived.

Passive elementary areas, are realized by a method including a local chemical modification step of the organic material. For example, the chemical modification may correspond to a destruction of the double binding, to a conductivity reduction of the organic

material, to a modification of the absorption properties of the organic material, or to a photo-oxidization of the organic material obtained by a bleaching process in oxygen atmosphere. The photo-oxidation of the polymer locally destroys and deactivate the polymer, which results in a locally high-impedance behaviour, and does not give any current under radiation of a light spot. When applying an input light spot on a passive area, an output signal having a second state is generated by the corresponding LED segment so that a second state of the binary data is derived. The bleaching process results thus in a data pattern which can be easily read out and converted into a binary sequence for retrieving stored data from the layer L1. The data pattern can be written by a recorder apparatus generating an ultra violet irradiation modulated by the data to be stored, in an oxygen environment whose chemical reaction is illustrated by Fig.16. Alternatively, this step can be done during the manufacturing of the information carrier.

Alternatively, the passive areas can be defined by a method comprising a step of suppressing one of the electrodes of the LED segment (i.e. the anode or the cathode), leading to local areas where only one electrode remains.

Fig.14 illustrates by an example the macro-cell scanning of two adjacent macro-cell data in an information carrier according to the invention as described in Fig.13. The data pattern is created by defining active elementary areas (white rectangles) and passive elementary areas (black rectangles) in each LED segment. Sensor S3 faces a macro-cell data scanned optically by the light spot LS3, while sensor S4 faces a macro-cell data scanned optically by the light spot LS4. The light spots are simultaneously and laterally displaced (by actuation means not represented) along the scanning direction D so that a light spot each is applied on each elementary area of each macro-cell data. When a light spot is applied on an elementary area, the corresponding segment generates a two-levels output signal : a first level L when the scanned elementary area is passive and a second level H when the scanned elementary area is active. It allows generating transmission output signals T3 and T4 reflecting the binary data pattern stored in the layer L1.

Fig.15 depicts another improved information carrier comprising a plurality of layers stacked on top of each other : a first layer L1 and a second layer L2 as described in Fig.13. The number of layers in this figure is limited to two just for facilitating the understanding.

This multilayer information carrier is made possible by the use of LED segments having a substantially transparent substrate, and comprising substantially transparent electrodes for example made of indium-tinoxide (ITO).

Preferably, the LED segments of the first layer L1 face the LED segments of the second layer L2. A single light spot is applied on elementary areas of the first layer L1, but since this layer is substantially transparent, the light spot is also simultaneously applied on elementary areas of the second layer L2. This allows to generate simultaneously two output signals reflecting the binary data pattern stored either in layer L1 and in layer L2.

Advantageously, for improving the signal-to-noise ratio of the readout signal generated by the LED segments, a lock-in amplification can be performed. To this end, the frequency of the input light spots are modulated to a known high frequency, and then the readout signals generated by the LED segments are amplified around this known frequency.

Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in the claims. Use of the article "a" or "an" preceding an element or step does not exclude the presence of a plurality of such elements or steps.

CLAIMS

1. Information carrier comprising :
   - a mask layer (ML) defining a data pattern,
   - a detection layer (DL) stacked on said mask layer (ML) and comprising at least one segment made of organic photosensitive material embedded between electrodes for detecting said data pattern.

2. Information carrier as claimed in claim 1 wherein the data pattern is made of substantially transparent and non-transparent elementary areas.

3. Information carrier as claimed in claim 1 or 2 wherein the at least one segment is sized for facing a plurality of said elementary areas.

4. Information carrier comprising a layer (L1) comprising at least one segment, said at least one segment comprising active and passive elementary areas for defining a data pattern, said at least one segment being made of organic photosensitive material embedded between electrodes for detecting said data pattern.

5. Information carrier comprising a plurality of layers (L1, L2) stacked on top of each other, each layer comprising at least one segment, said at least one segment comprising active and passive elementary areas for defining a data pattern, said at least one segment being made of organic photosensitive material embedded between electrodes for detecting said data pattern.

6. Information carrier as claimed in claim 4 or 5 wherein the passive elementary areas correspond to chemically modified areas of the organic photosensitive material, or to areas with only one electrode.

7. Information carrier as claimed in claim 1, 4 or 5 wherein the organic photosensitive material embedded between electrodes is made of OLEDs, smOLEDs, PolyLED, LEECs, organic photovoltaic cells, or hybrid organic/inorganic solar cell known as Grätzel cell.

8. Method of defining a data pattern in an information carrier comprising a detection layer, said data pattern deriving from a step of printing dark elementary areas on said detection layer.

9. Method of defining a data pattern in an information carrier comprising a layer made of organic photosensitive material, said data pattern deriving from a step of modifying the properties of said material for creating passive elementary areas.

10. Method of defining a data pattern in an information carrier comprising a layer made of organic photosensitive material embedded between dectrodes, said data pattern deriving from a step of suppressing one of said electrodes for creating passive elementary areas.

ABSTRACT

The invention relates to an information carrier comprising :

- a mask layer (ML) defining a data pattern,
- a detection layer (DL) stacked on said mask layer (ML) and comprising at least one segment made of organic photosensitive material embedded between electrodes for detecting said data pattern.

Use : Optical storage

Ref : Fig.11

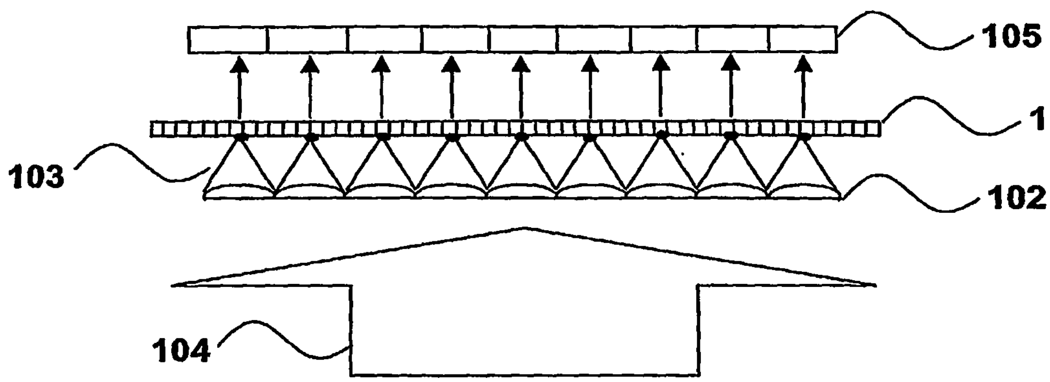

FIG.1

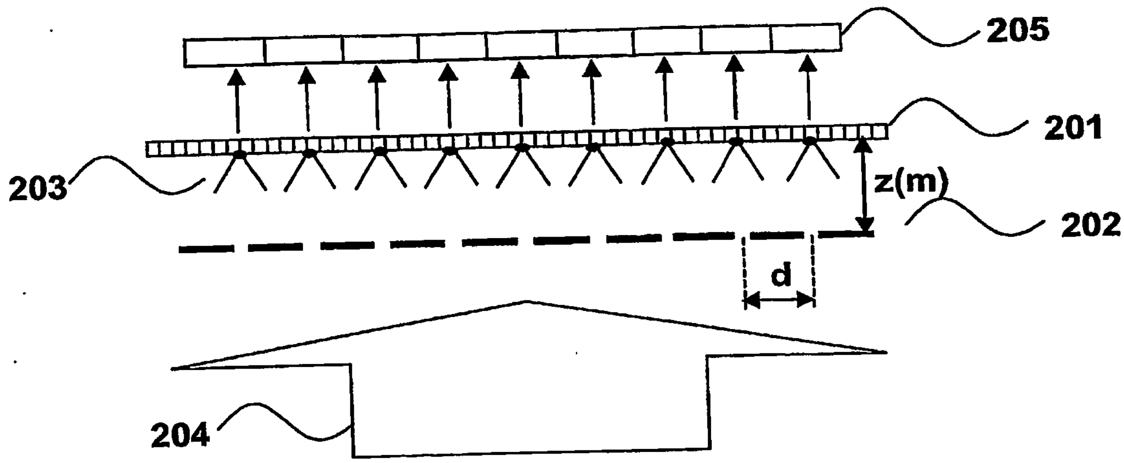

FIG.2

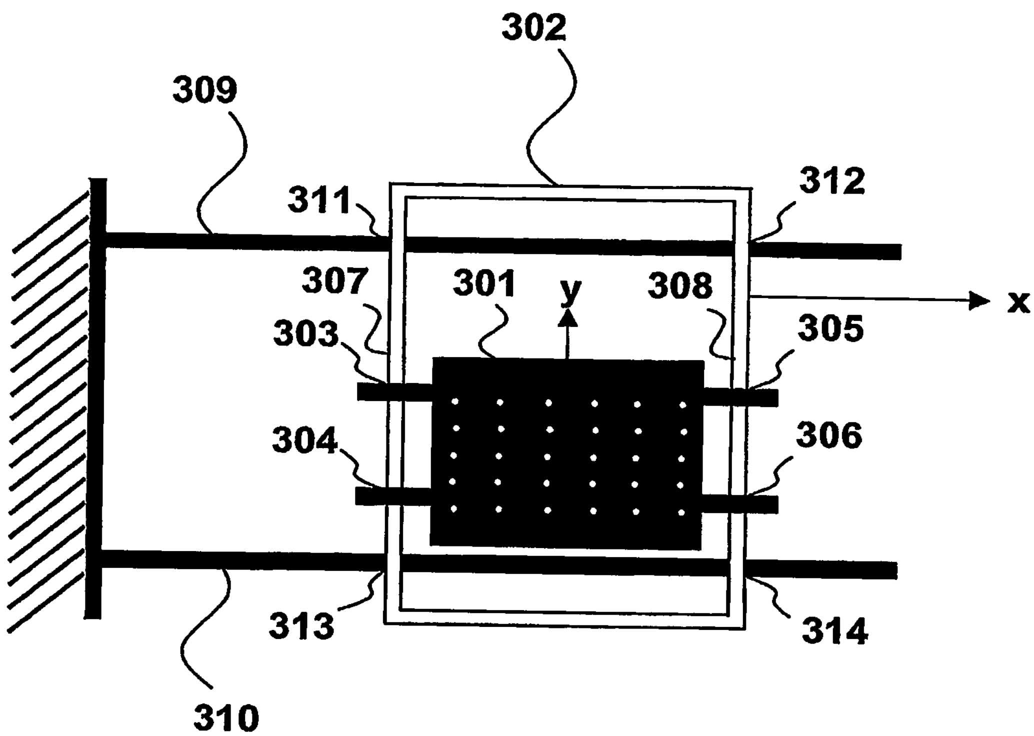

FIG.3

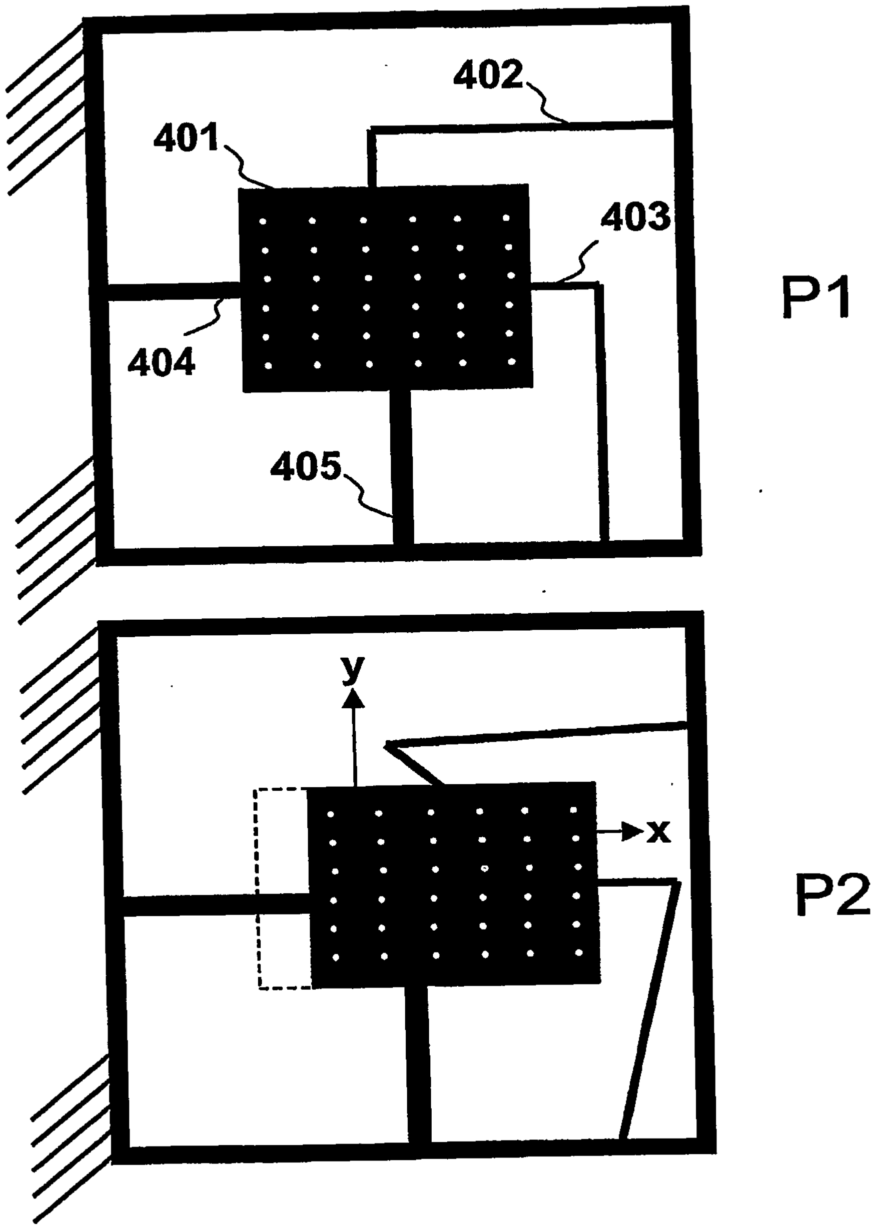

FIG.4

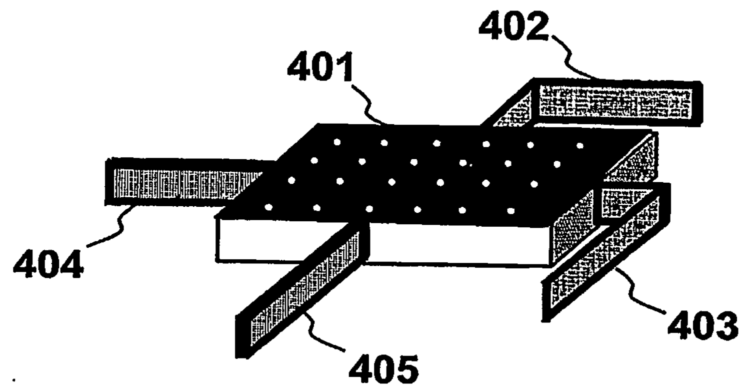

FIG.5

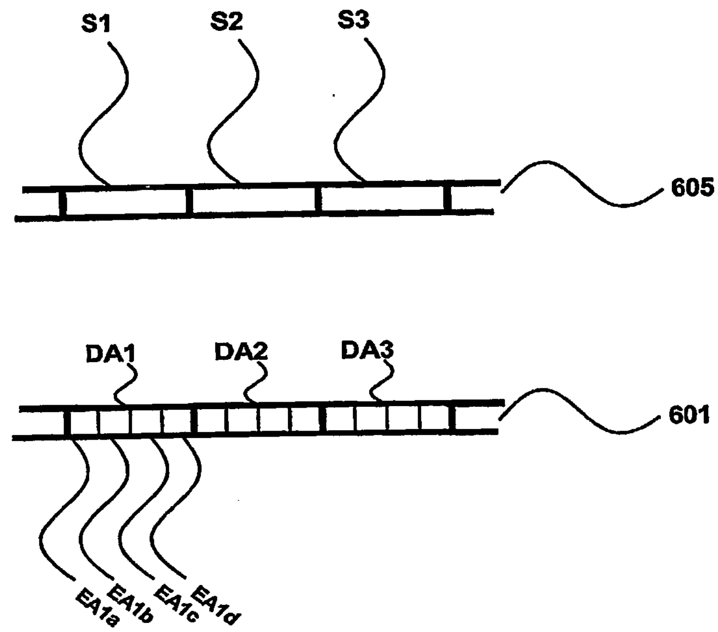

FIG.6

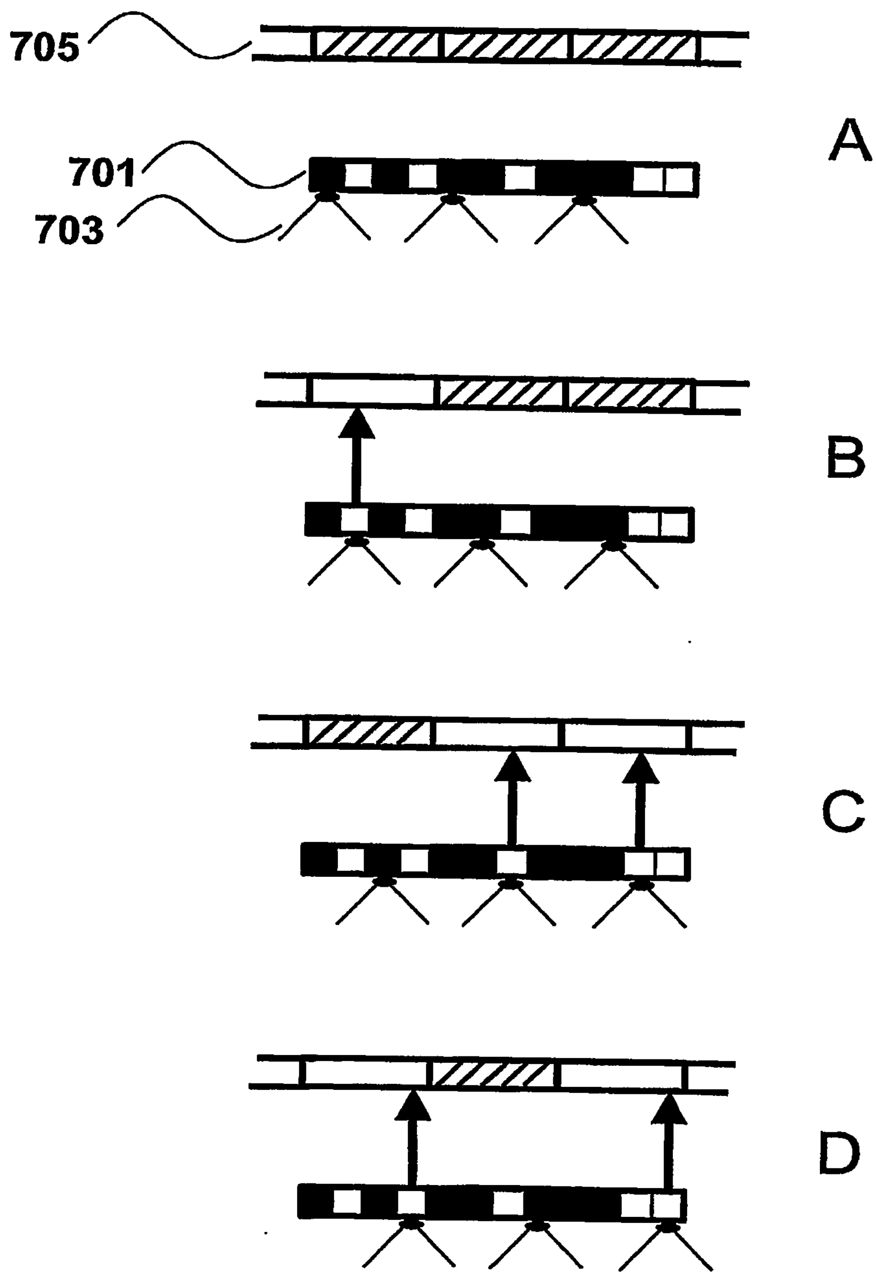

FIG.7

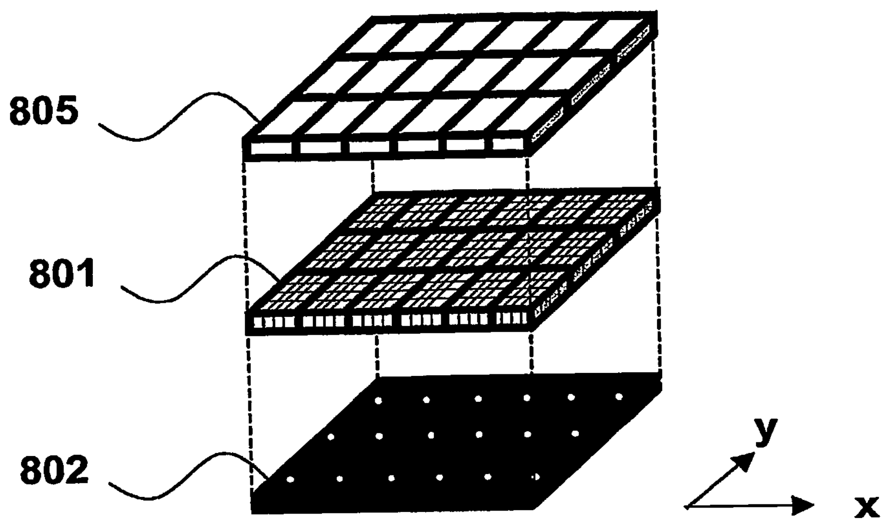

FIG.8

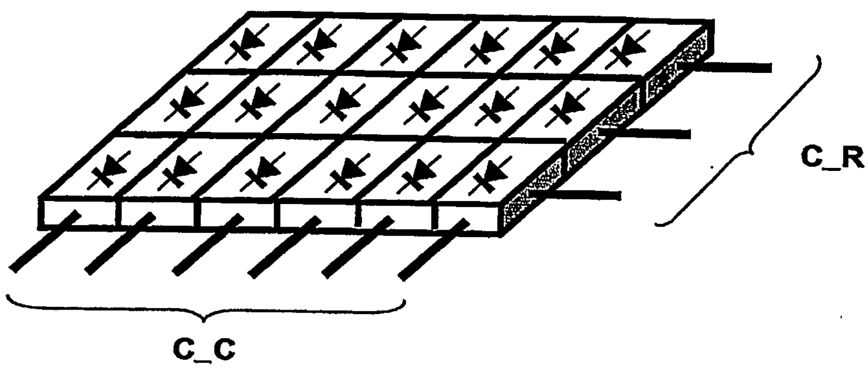

FIG.9

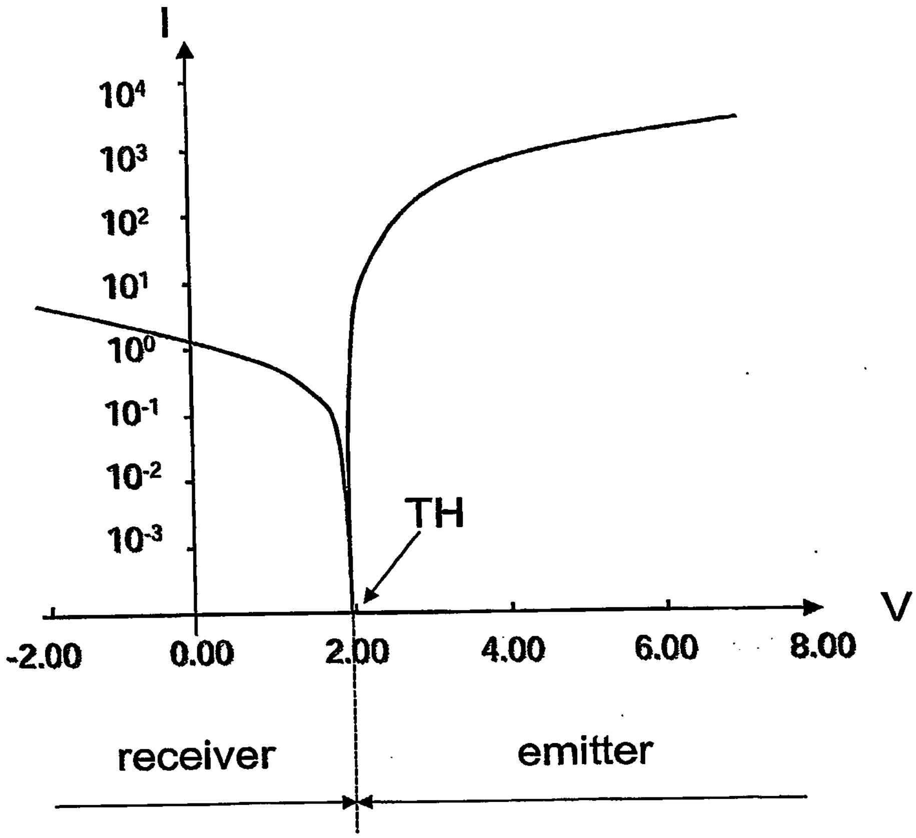
I
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
TH
V
-2.00
0.00
2.00
4.00
6.00
8.00
receiver
emitter

FIG.10

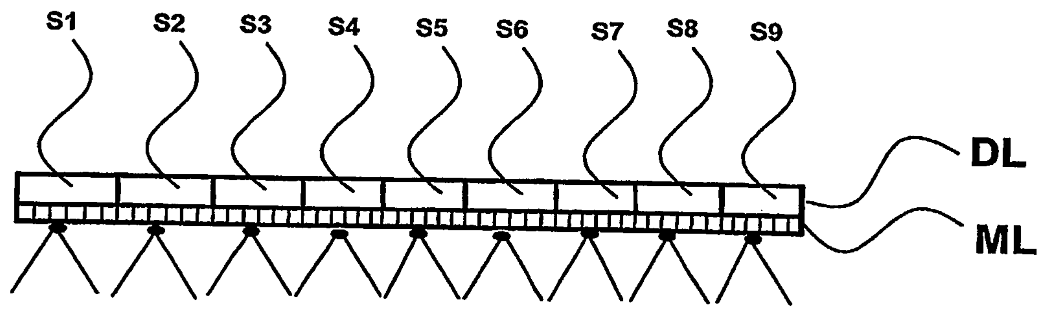

FIG.11

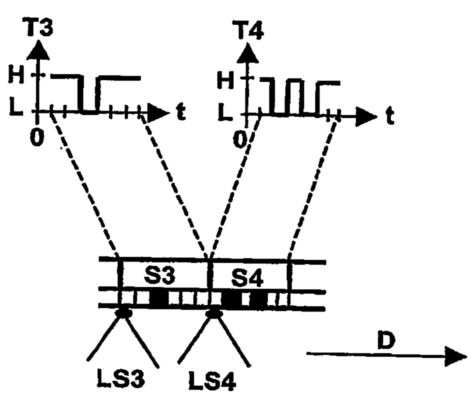

FIG.12

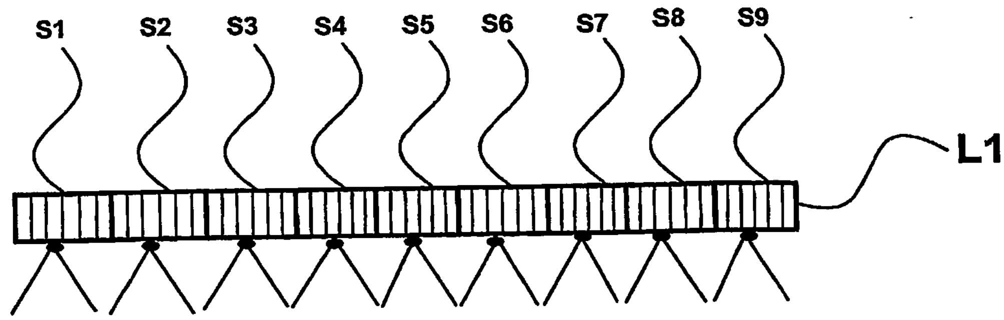

FIG.13

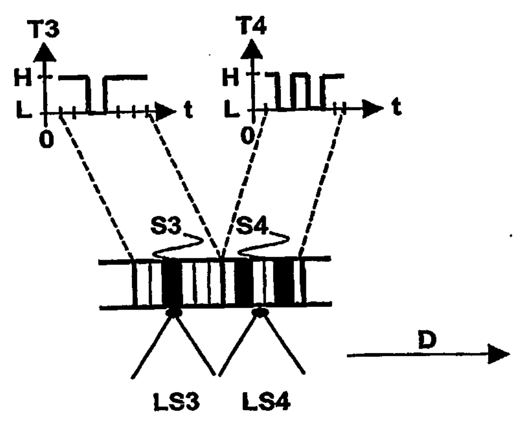

FIG.14

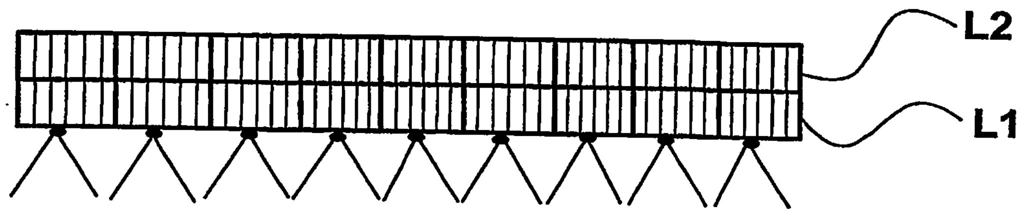

FIG.15

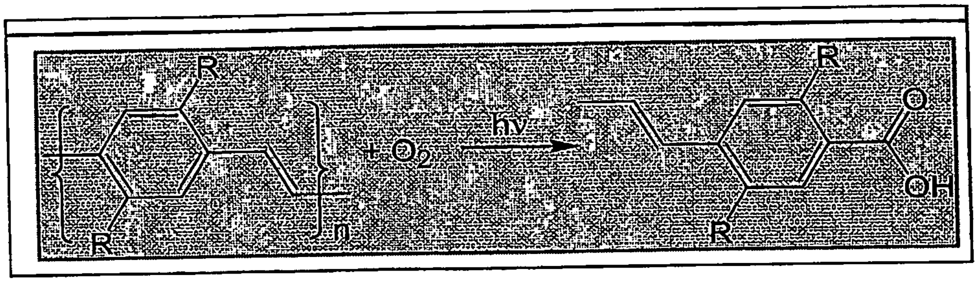

FIG.16